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(54) Vibration damping in switched reluctance motors

(57) A switched reluctance motor includes a housing 11 having an inner bore 11d extended in the axial direction, a stator 12 disposed in said inner bore of said housing and having a plurality of pairs of opposing stator pole portions which project inwards in the diametrical direction and which extend in the axial direction, and an absorbing means for absorbing vibrations of said stator disposed between said stator and said housing. The absorbing means may be grease 23 or O'-rings 50, 51. Alternatively fibre glass (Fig 6) or grease (Fig 4) may be incorporated into the housing.

Fig. 2

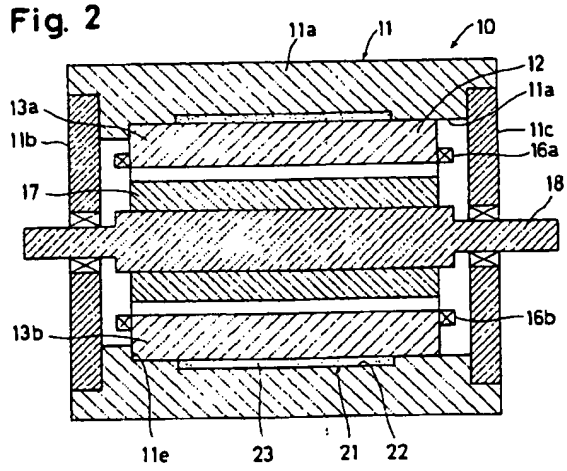
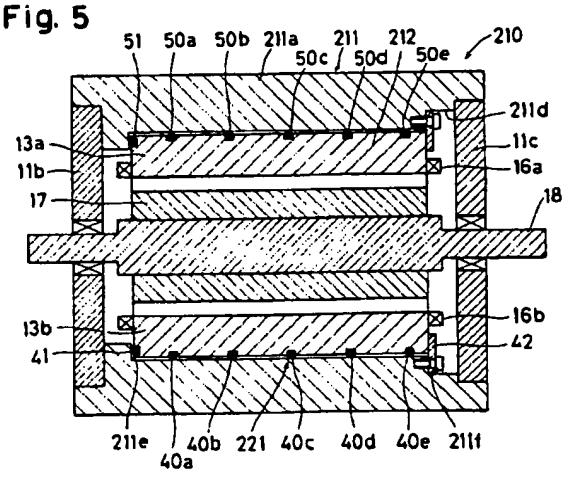


Fig. 5



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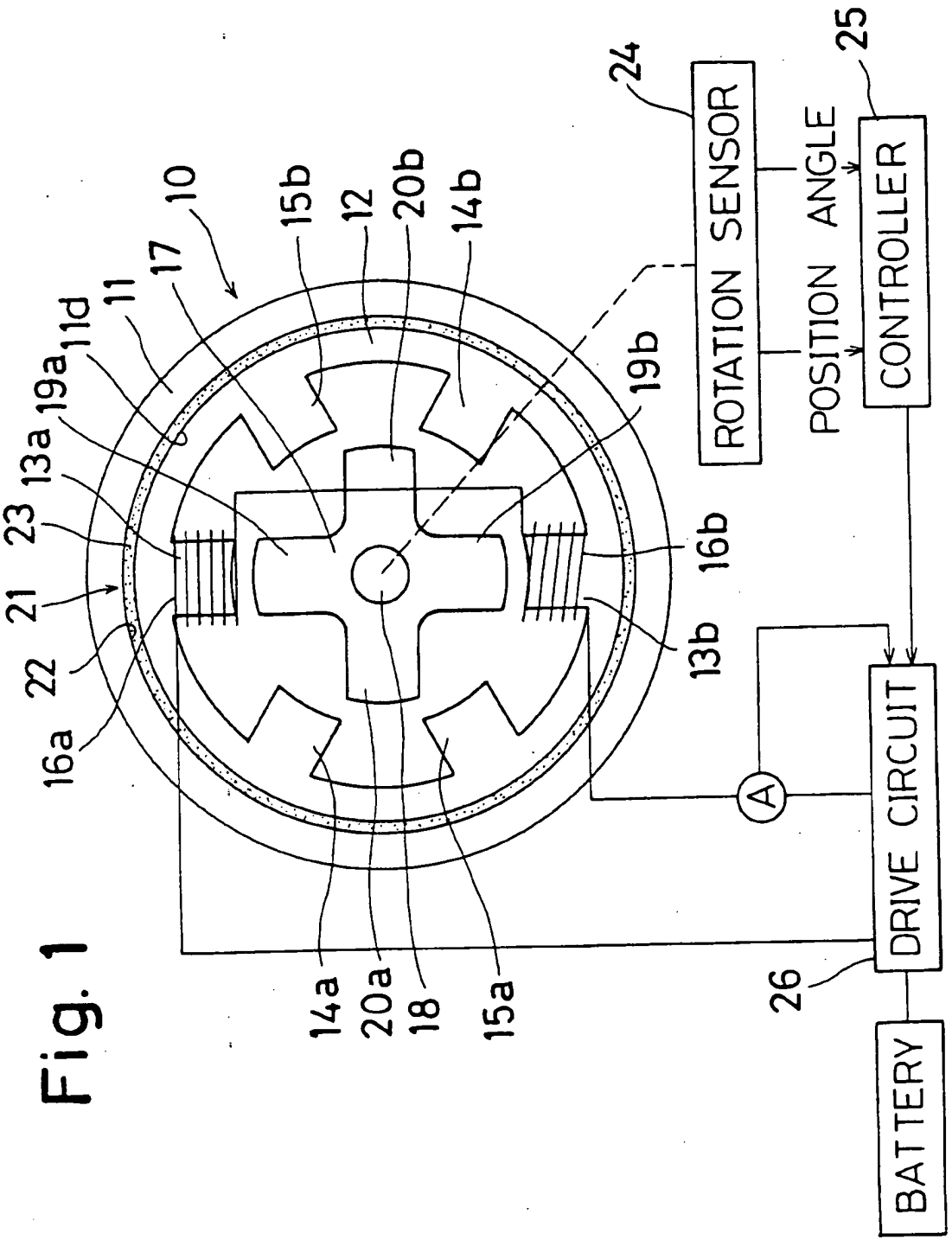

10
11
11d
12
13a
13b
14a
14b
15a
15b
16a
16b
17
18
19a
19b
20a
20b
21
22
23
24
25
26
ROTATION SENSOR
POSITION ANGLE
CONTROLLER
DRIVE CIRCUIT
BATTERY
A

Fig. 1

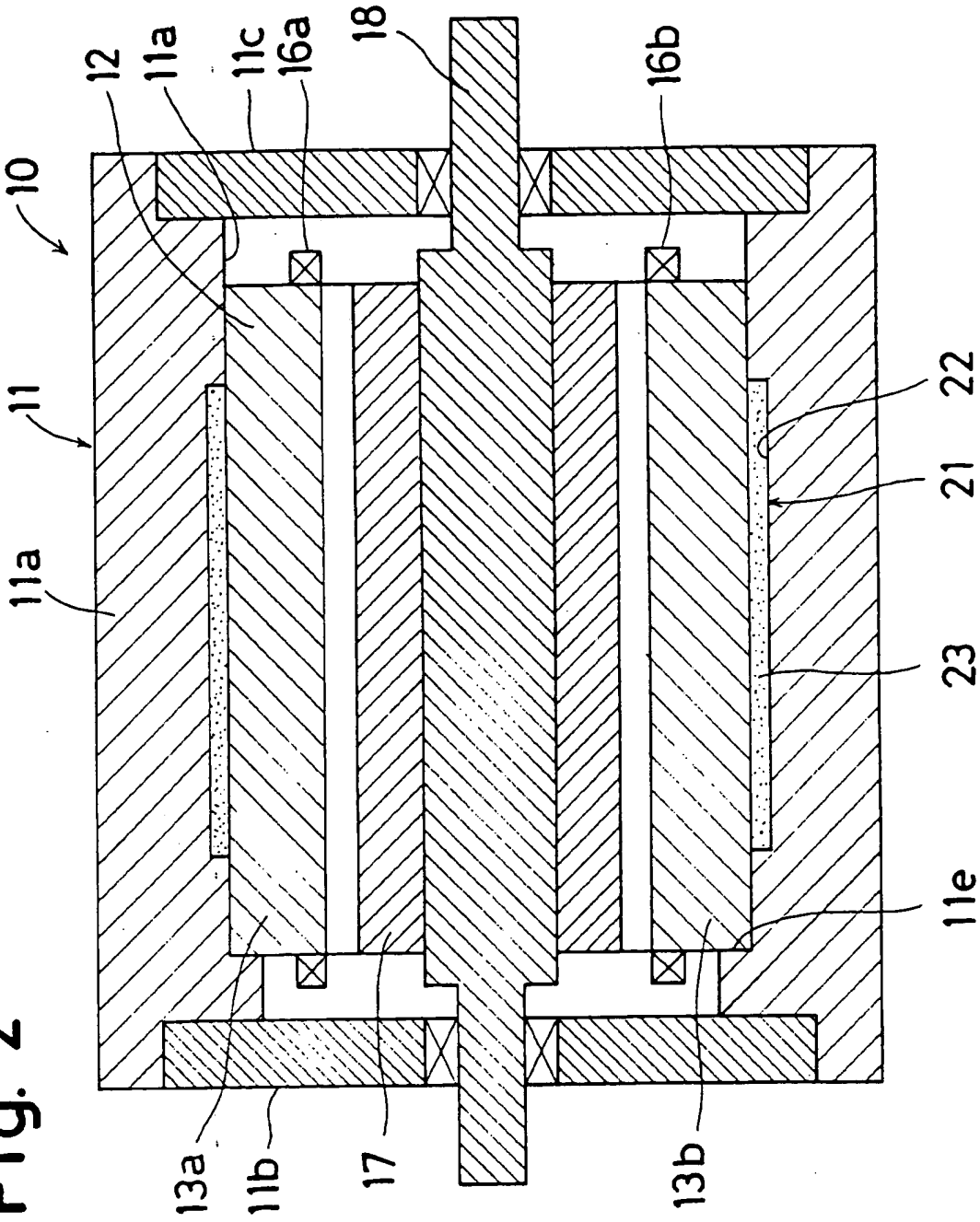
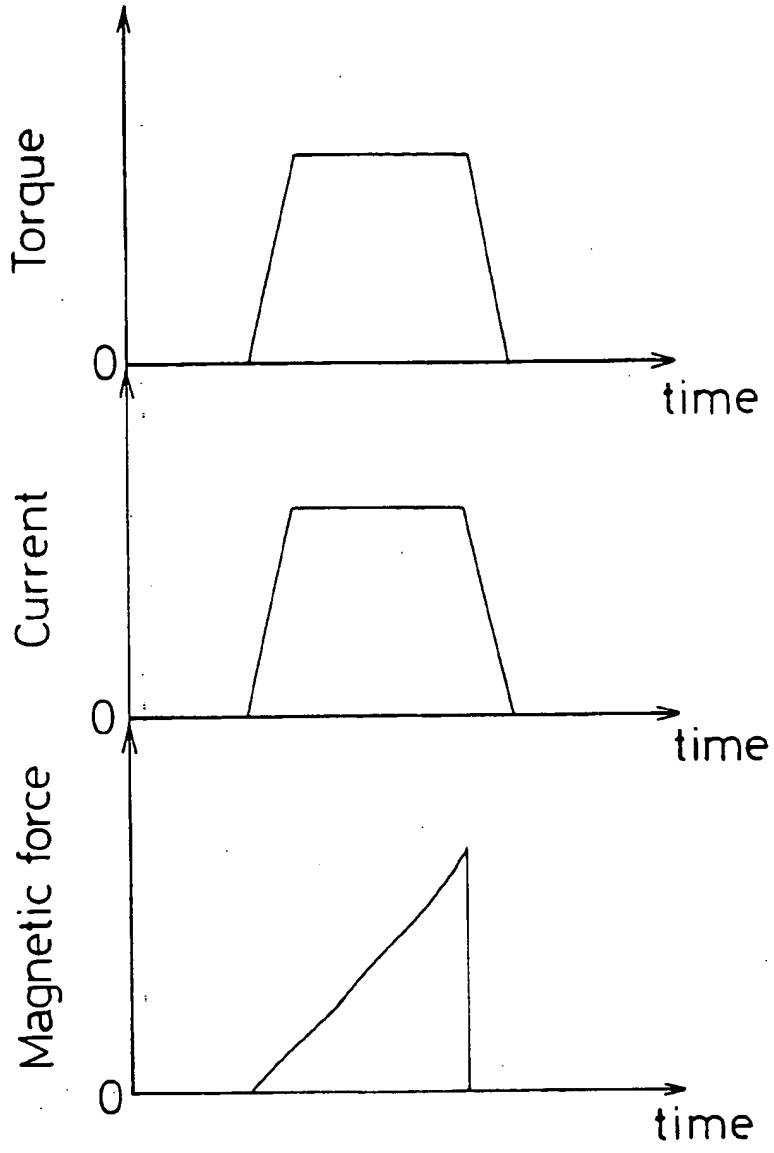


Fig. 2

Fig. 3



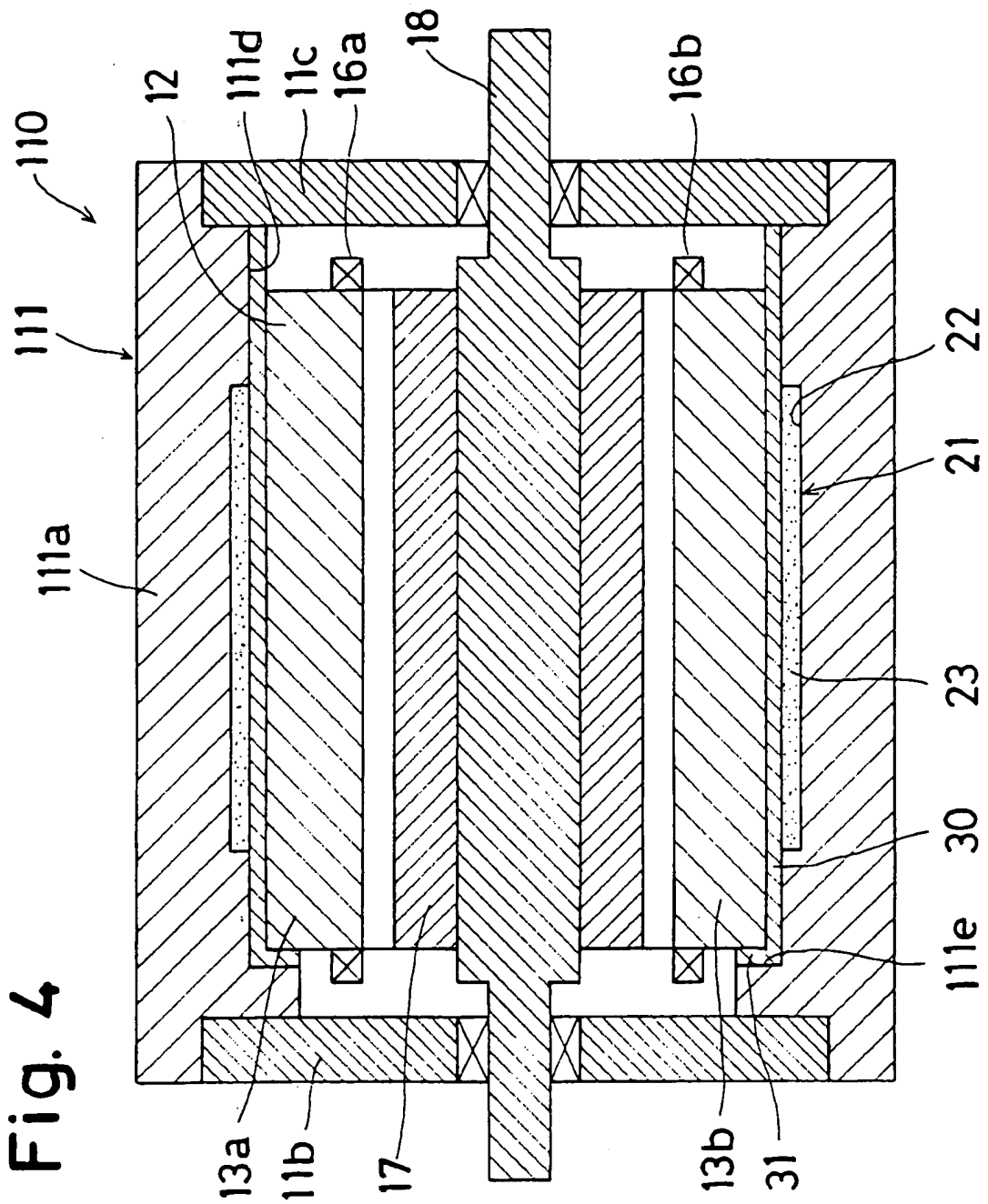

110
111
111a
12
111d
11c
16a
18
16b
22
21
23
30
111e
13a
11b
17
13b
31

Fig. 4

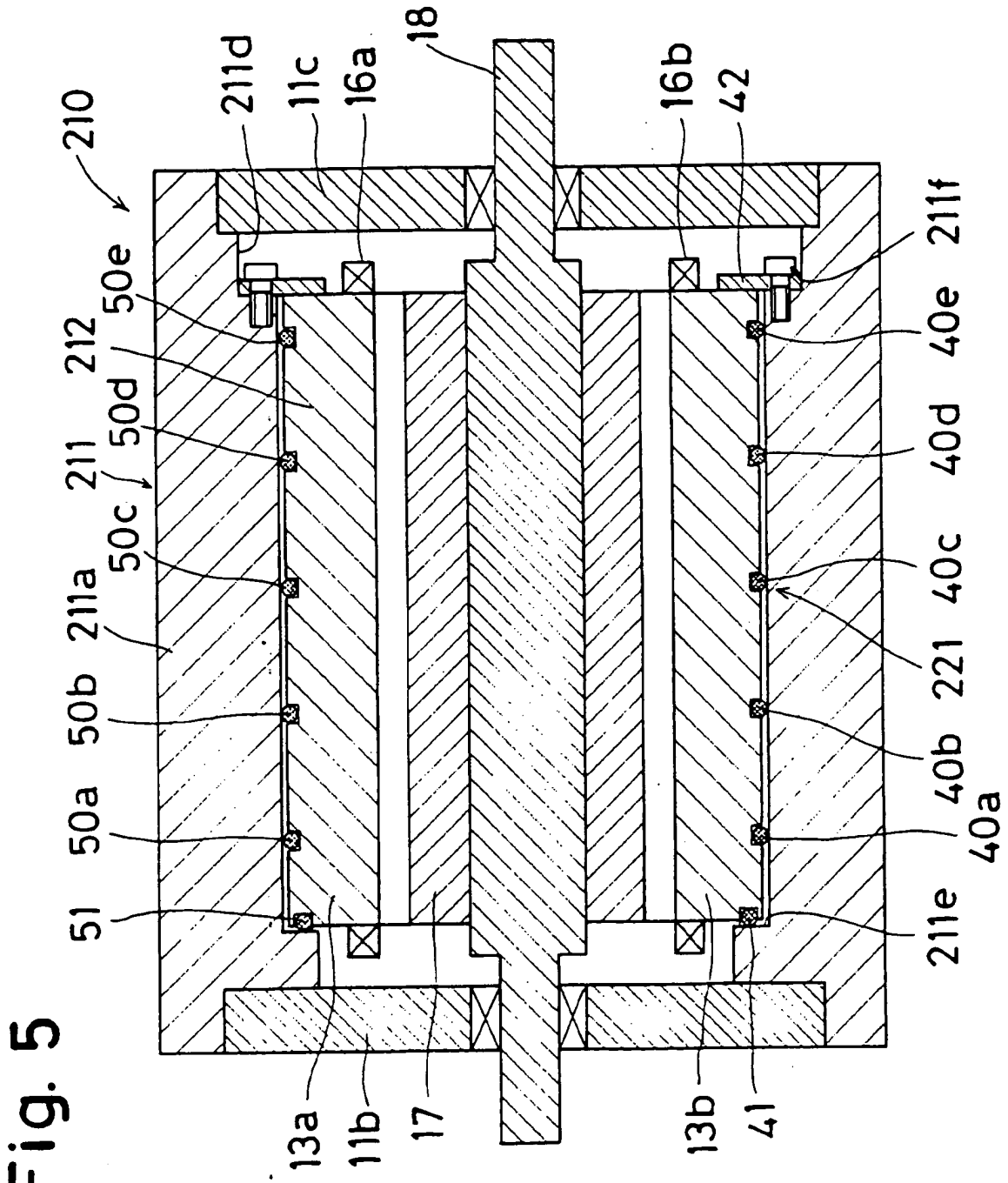

210
211d
11c
16a
18
16b
42
211f
50e
212
40e
50d
211
40d
50c
211a
40c
221
50b
40b
50a
40a
51
211e
13a
11b
17
13b
41

Fig. 5

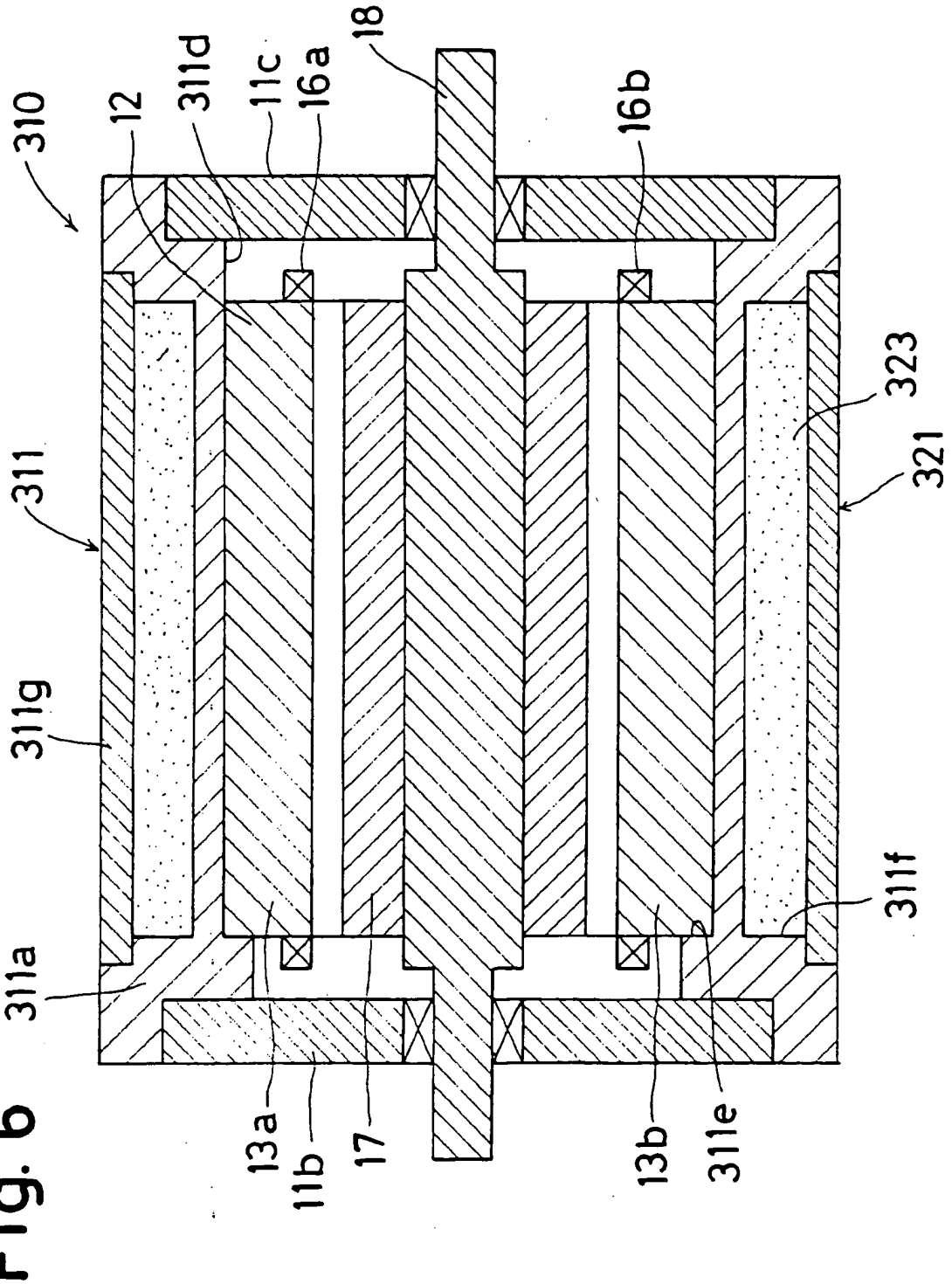

310
12
311d
11c
16a
18
16b
323
321
311
311g
311a
311f
13a
11b
17
13b
311e

Fig. 6

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TITLE

Switched reluctance motor

BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to a switched reluctance motor.

2. Description of the prior art

A conventional switched reluctance motor is disclosed in, for example, GB 2231214A. This switched reluctance motor includes a housing, a stator fixed in an inner bore of the housing and formed by laminating electromagnetic steel plates and a rotor disposed in the stator and formed by laminating electromagnetic steel plates. The rotor is fixed to an output shaft which is rotatably supported on the housing and thereby is rotatably disposed in the stator. The rotor has a plurality of pairs of rotor pole portions which project outwards in the diametrical direction and which extend in the axial direction. The stator has a plurality of pairs of opposing stator pole portions which project inwards in the diametrical direction and which extend in the axial direction. Each of the stator pole portions moves past each of the rotor pole portions as the rotor rotates and a certain clearance is maintained between stator pole portions and rotor pole portions which are opposite each other. On each of the stator pole portions, a coil is wound. The coils which are wound on each of the pairs of opposing stator pole portions are connected in series with each other and thereby a magnetic flux is generated between the pair of stator pole portions when current is supplied to the coils that are wound thereon. A magnetic attracting force results between rotor pole portions and stator pole portions which are approaching each other. This magnetic attracting force is changed by

controlling supply current by means of switching elements in response to the rotational position of the rotor and thereby motoring torque is produced.

The current which is supplied to the coils wound on one pair or several pairs of rotor pole portions being approached by one pair or several pairs of rotor pole portions is switched on and off as a pulse. In general, the current is switched on when a pair of rotor pole portions begins to be aligned with a pair of stator pole portions, and the current is switched off before the pair of rotor pole portions is fully aligned with the pair of stator pole portions. Thereby, the magnetic attracting force increases while the current is supplied, and disappears in a moment when the current is switched off. On one hand motoring torque is obtained by this magnetic attracting force. On the other hand a pair or several pairs of stator pole portions are attracted radially to a pair of rotor pole portions by this magnetic attracting force, and thereby the stator and the housing are strained. When the magnetic attracting force disappears, the strain of the stator reduces suddenly and simultaneously the housing is pressed outwards in the diametrical direction by the stator. This impulsive variation of the housing is generated periodically in response to the rotation of the rotor and thereby vibration of the housing generates objectionable acoustic noise.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an improved switched reluctance motor which overcomes the above drawbacks.

It is another object of the present invention to provide an improved switched reluctance motor which can reduce the objectionable acoustic noise.

In order to achieve these objectives, there is provided a switched reluctance motor comprising; a housing having an inner bore extended in the axial direction, a stator disposed in said inner bore of said housing and having a plurality of pairs of opposing stator pole portions which project inwards in the diametrical direction and which extend in the axial direction, a rotor rotatably disposed in said stator and having a plurality of rotor pole portions which project outwards in the diametrical direction and which extend in the axial direction, a plurality of coils wound on said pairs of stator pole portions, and an absorbing means for absorbing vibrations of said stator disposed between said stator and said housing.

Alternatively, the absorbing means for absorbing vibrations of the stator may comprise an absorbing material disposed in a sealed cylindrical groove within the housing.

BRIEF DESCRIPTION OF THE DRAWINGS

Additional objects and advantages of the present invention will become more apparent from the following detailed description of preferred embodiments thereof when considered with reference to the attached drawings, in which:

Fig. 1 is a schematic view of a first embodiment of a switched reluctance motor in accordance with the present invention;

Fig. 2 is a longitudinal sectional view of a first embodiment of a switched reluctance motor in accordance with the present invention;

Fig. 3 is a set of graphs which show variations of torque, current and magnetic attracting force during the supply of current to a coil of a first embodiment of a switched reluctance motor in accordance with the present

invention;

Fig. 4 is a longitudinal sectional view of a second embodiment of a switched reluctance motor in accordance with the present invention;

Fig. 5 is a longitudinal sectional view of a third embodiment of a switched reluctance motor in accordance with the present invention; and

Fig. 6 is a longitudinal sectional view of a fourth embodiment of a switched reluctance motor in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A switched reluctance motor constituted in accordance with preferred embodiments of the present invention will be described with reference to the attached drawings.

Fig. 1 and Fig. 2 show a first embodiment of a switched reluctance motor in accordance with the present invention. Referring to Fig. 1 and Fig. 2, a switched reluctance motor 10 is provided with a housing 11 which is made of aluminium. The housing 11 is composed of a cylindrical portion 11a and side housings 11b, 11c which are fixed to ends of the cylindrical portion 11a. In an inner bore 11d of the cylindrical portion 11a, a cylindrical stator 12 is disposed. The stator 12 is formed by laminating electromagnetic steel plates and is fixed at its outer circumferential portion to the inner bore 11d of the housing 11 by heat shrinking.

The stator 12 is provided with three pairs of opposing stator pole portions 13a, 13b; 14a, 14b; 15a, 15b which project inwards in the diametrical direction at regular angular intervals and which extend in the axial direction. On each pair of stator pole portions, for example on a pair of stator pole portions 13a, 13b, coils 16a, 16b are wound respectively and are connected in series with each other. Coils (not shown) are wound on

each of the other pairs of stator pole portions 14a, 14b, and 15a, 15b, and connected in pairs in series. These coils are all connected to a drive circuit 26.

In this embodiment, an absorbing means 21 is disposed between the inner bore 11d of the housing 11 and an outer circumferential surface of the stator 12. The absorbing means 21 includes a sealed cylindrical groove 22 formed in the inner bore 11d of the housing 11. An absorbing material 23 such as grease having high thermal conductivity is filled in the cylindrical groove 22. The axial length of the cylindrical groove 22 is more than 50% of the axial length of the stator 12 and thereby the absorbing means 21 absorbs the vibrations of the stator 12 without lowering the fixing strength of the stator 12. The inner bore 11d of the housing 11 has a stepped portion 11e. The stepped portion 11e contacts with an outer circumferential edge portion of the stator 12 and thereby the stator 12 is located in the axial direction by the stepped portion 11e.

A rotor 17 which is formed by laminating electromagnetic steel plates is fixed on an output shaft 18 which is rotatably supported on the side housings 11b, 11c at both ends. Thereby, the rotor 17 is able to rotate with the output shaft 18 in the stator 12. Furthermore, the rotor 17 is provided with two pairs of opposing rotor pole portions 19a, 19b; 20a, 20b which project outwards in the diametrical direction at regular angular intervals and which extend in the axial direction. As shown in Fig. 1, each of these rotor pole portions 19a, 19b; 20a, 20b is able to be opposed to each of the stator pole portions 13a, 13b; 14a, 14b; 15a, 15b while maintaining a certain clearance therebetween as the rotor 17 rotates.

A well known rotation sensor 24, such as an encoder or a resolver, is disposed on the end (not shown) of the output

shaft 18 in order to detect the rotation position of the rotor 17. The rotation sensor 24 is electrically connected to a controller 25 and a position signal and an angle signal detected by the rotation sensor 24 are transmitted to the controller 25.

The controller 25 is electrically connected to the drive circuit 26 to which the coils wound on each of the stator pole portions 13a, 13b; 14a, 14b; 15a, 15b are connected and transmits an output signal to the drive circuit 26 in response to a position signal and an angle signal of the rotation sensor 24. The drive circuit 26 is composed of an inverter using switching elements such as transistors or thyristors and supplies current, which may be in the form of a pulse, to each of the coils in response to the output signal of the controller 25.

The above described embodiment of the switched reluctance motor 10 operates as follows:
When it is detected by the rotation sensor 24 that the rotor 17 is in a predetermined position in which one of the two pairs of rotor pole portions 19a, 19b; 20a, 20b begins to be opposed to one of the three pairs of stator pole portions 13a, 13b; 14a, 14b; 15a, 15b, the controller 25 transmits an output signal responding to the detected signal of the rotation sensor 24 to the drive circuit 26. The drive circuit 26 supplies current to the coils which are wound on the pair of stator pole portions opposing the pair of rotor pole portions in response to the output signal of the controller 25. Thereby, the stator pole portions on which these coils are wound are magnetized and a magnetic flux is generated between the magnetized stator pole portions. A magnetic attracting force results between the rotor pole portions and the stator pole portions which are opposing each other and a torque acts on the rotor 17 by a component of the magnetic attracting force tending to pull the rotor

pole portions to exactly opposite the stator pole portions.

When the rotor 17 is rotated by the torque and it is detected by the rotation sensor 24 that the rotor 17 is in a predetermined position in which the pair of rotor pole portions is just before a position exactly opposite the pair of magnetized stator pole portions, that is to say, it is detected by the rotation sensor 24 that the rotor 17 is in a final effective position in which the above component force acts on the rotor 17, the drive circuit 26 stops supplying the current to the coils wound on the magnetized stator pole portions in response to an output signal of the controller 25. As mentioned above, the current which is supplied to the coils wound on a pair of the stator pole portions opposing a pair of rotor pole portions is switched on and off such as a pulse and a certain motoring torque is obtained by the action of the above magnetic attracting force. Fig. 3 shows variations of the torque, the current, and the magnetic attracting force during the above supply of the current to the coils which are wound on a pair of stator pole portions. The above on-off timing of the supply of the current is determined in response to the demand of the rotational speed or the torque of the switched reluctance motor.

On the other hand, when a pair of magnetized stator pole portions is attracted to an opposing pair of rotor pole portions by the above magnetic attracting force, the stator 12 is thereby strained. For example, in Fig. 1 and Fig. 2, a pair of stator pole portions 13a, 13b which is opposite a pair of rotor pole portions 19a, 19b is magnetized by supplying current to the coils 16a, 16b and is attracted to a pair of rotor pole portions 19a, 19b. As a result, the stator 12 is strained so that the diameter of the stator 12 is shortened in the vertical

direction in Fig. 1. When the magnetic attracting force disappears by the switching off of the current, the strain of the stator 12 reduces suddenly. Thereby, impulsive variation of the stator 12 is generated periodically by the magnetization of each of the plurality of pairs of stator pole portions 13a, 13b; 14a, 14b; 15a, 15b and the stator 12 vibrates in the diametrical direction.

In this embodiment, the absorbing means 21 effectively prevents transmittal of this vibration of the stator 12 to the housing 11. Namely, most of the vibration of the stator 12 is absorbed by the absorbing material 22 and the vibration of the stator 12 is hardly transmitted to the housing 11. Accordingly, the vibration of the housing 11 caused by the vibration of the stator 12 is reduced and thereby the objectionable acoustic noise caused by the vibration of the housing 11 is reduced. Now, since the absorbing material (grease) 22 has high thermal conductivity and therefore the heat of the stator 12 heated by the magnetization is effectively transferred to the housing 11 through the grease 22, the stator 12 is not thermally insulated and is effectively cooled.

Fig. 4 shows a second embodiment of the present invention. In Fig. 4, the same parts as compared with Fig. 1 and Fig. 2 are identified by the same reference numerals. Referring to Fig. 4, a switched reluctance motor 110 has a sleeve 30 which is interposed between the stator 12 and the cylindrical portion 111a of the housing 111 and which is fixed to the inner bore 111d of the housing 111 by heat shrinking. The sleeve 30 is made of aluminium and has a flange portion 31 which projects inwards in the diameterical direction at one end. The stator 12 is fixed to the inner wall of the sleeve 30 by heat shrinking. An outer circumferential edge portion of the stator 12 contacts with an inner surface of the

flange portion 31 and thereby the stator 12 is located in the axial direction by the flange. According to this embodiment, the sleeve 30 is strained with the stator 12 and vibrates with the stator 12 as one body. As mentioned in the first embodiment, most of this vibration of the stator 12 and the sleeve 30 is absorbed by the absorbing material 22 such as grease of the absorbing means 21 and the vibration of the stator 12 is hardly transmitted to the housing 111. Accordingly, it is possible to obtain the same effects as the above first embodiment. Since the other structures are the same as the first embodiment, the description is omitted.

Fig. 5 shows a third embodiment of the present invention. In Fig. 5, the same parts as compared with Fig. 1 and Fig. 2 are identified by the same reference numerals. Referring to Fig. 5, a switched reluctance motor 210 has a stator 212 which is provided with five circular grooves 50a, 50b, 50c, 50d, 50e on its outer circumferential surface and O-rings 40a, 40b, 40c, 40d, 40e made of rubber are fitted into the grooves 50a, 50b, 50c, 50d, 50e respectively as the absorbing means 221 of the present invention. A cylindrical portion 211a of the housing 211 has an inner bore 211d which is provided with two stepped portions 211e, 211f. The stator has a circular groove 51 formed on an outer circumferential edge portion of the end portion of the surface which is opposite to the stepped portion 211e of the housing 211. An O-ring 41 is fitted into the groove 51. The stator 212 is fitted into the inner bore 211d of the housing 211 and the O-rings 40a, 40b, 40c, 40d, 40e, 41 are contacted with the surface of the inner bore 211d of the housing 211 in order to locate the stator 212 in the diametrical direction. A ring-shaped retainer 42 which is engaged with the other side surface of the stator 212 is fixed on the stepped portion 211f of the housing 211 and thereby the stator 212 is always pressed toward the stepped

portion 211e so as not to rotate with the rotor 17 and so as to be located in the axial direction. According to this embodiment, most of the vibration of the stator 212 is absorbed by the O-rings 40a, 40b, 40c, 40d, 40e and the vibration of the stator 212 is hardly transmitted to the housing 211. Accordingly, it is possible to obtain the same effects as the first embodiment. The small gap between the outer circumferential surface of the stator 212 and the inner bore 211d of the housing 211 could be filled with heat conductive material such as grease.

Fig. 6 shows a fourth embodiment of the present invention. In Fig. 6, the same parts as compared with Fig. 1 and Fig. 2 are identified by the same reference numerals. Referring to Fig. 6, a switched reluctance motor 310 has a cylindrical portion 311a of the housing 311 which is provided with a cylindrical groove 311f on its outer circumferential surface. The longitudinal length of the groove 311f is the same as the length of the stator 12. A casing 311g is fixed to the cylindrical portion 311a so as to surround the groove 311f and thereby the groove 311f is sealed. In the sealed groove 311f, a sound absorbing material such as glass fibre 323 is filled. According to this embodiment, when the vibration of the stator 12 is transmitted to the cylindrical portion 311a, most of the vibration of the stator 12 is absorbed by the glass fibre 323. Furthermore, the objectionable acoustic noise caused by the vibration of the housing 311 is absorbed by the glass fibre 323.

In the above mentioned four embodiments, the present invention is applied to a switched reluctance motor which includes a stator having three pairs of stator pole portions and a rotor having two rotor pole portions. However, it is possible to apply the present invention to other types of switched reluctance motors, for example a

switched reluctance motor which includes a stator having six pairs of stator pole portions and a rotor having four pairs of rotor pole portions.

As mentioned above, according the present invention, most of the vibration of the stator is absorbed by the absorbing means and the vibration of the stator is hardly transmitted to the housing. Accordingly, the vibration of the housing caused by the vibration of the stator is reduced and thereby it is possible to reduce the objectionable acoustic noise caused by the vibration of the housing.

CLAIMS:

1. A switched reluctance motor comprising;

a housing having an inner bore extended in the axial direction,

a stator disposed in said inner bore of said housing and having a plurality of pairs of opposing stator pole portions which project inwards in the diametrical direction and which extend in the axial direction,

a rotor rotatably disposed in said stator and having a plurality of rotor pole portions which project outwards in the diametrical direction and which extend in the axial direction,

a plurality of coils wound on said pairs of stator pole portions, and

an absorbing means for absorbing vibrations of said stator disposed between said stator and said housing.

2. A switched reluctance motor as recited in claim 1, wherein said stator is fixed to said inner bore of said housing and said absorbing means includes a circular groove which is formed on said inner bore of said housing and an absorbing material which is filled in said groove.

3. A switched reluctance motor as recited in claim 2, wherein a generally cylindrical sleeve is also disposed between said stator and said inner bore of said housing.

4. A switched reluctance motor as recited in claim 1, wherein said stator is provided with a plurality of circular grooves on its outer circumferential surface and said absorbing means includes a plurality of O-rings which are fitted into said grooves of said stator and which are contacted with said inner bore of said housing.

5. A switched reluctance motor substantially as described herein with reference to Figure 2, 4, 5 or 6.

The Patent Office

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Application No: GB 9419788.6
Claims searched: 1-5

Examiner: Mr J Cockitt
Date of search: 28 September 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Int Cl (Ed.6): H02K [05/20, 05/24, 19/06, 19/10, 29/08, 29/10, 29/12, 29/14, 37/04, 37/16]; F16F [15/023, 15/04, 15/08, 07/00]

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP0240644A1	DUCELLIER - see figs 1-3 esp	1,4 at least
A	WO94/21024A1	BOSCH	
A	US5235227A	PANAVISION	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.